
CONTENTS

Preface	i
Acknowledgments	iii
Executive Summary	v
List of Illustrations	xvii
Acronyms and Abbreviations	xxiii
1. Introduction	1-1
1.1 Nuclear Wastes Addressed	1-2
1.2 Risk-Assessment Methodology	1-2
1.3 Scope of the Risk Assessment	1-4
2. Source-Term Analyses of Potential Radionuclide Releases Relevant to the Arctic Seas and Northwest Pacific Ocean	2-1
2.1 Existing Sources of Radionuclides in Arctic Waters	2-2
2.2 Description of Marine Disposal Sites	2-4
2.2.1 Kara Sea Marine Nuclear Reactors	2-4
2.2.2 Sea of Japan; Sea of Okhotsk; Pacific Ocean, East Coast of Kamchatka ...	2-9
2.3 Sources in the West Siberian Basin	2-15
2.4 Radionuclide Inventories	2-16
2.4.1 Kara Sea	2-16
2.4.2 Sea of Japan and Pacific Ocean, East Coast of Kamchatka	2-21
2.4.3 Sea of Okhotsk	2-21
2.4.4 West Siberian Basin	2-22
2.5 Radionuclide Screening	2-25
2.5.1 Kara Sea and West Siberian Sources	2-25
2.5.2 Northwest Pacific Ocean Sources	2-29
2.6 Release Scenarios	2-32
2.6.1 Kara Sea	2-32
2.6.2 West Siberian Basin	2-33
2.7 Summary	2-38
3. Transport of Radionuclides in the Arctic Seas	3-1
3.1 Selection Criteria for Radionuclide Transport Models	3-2
3.2 Simulating Radionuclide Transport in the Arctic Ocean	3-2
3.2.1 Mathematical Formalism for the Compartmental Model	3-4
3.2.2 Radionuclide Partitioning Between Sediment and Seawater	3-6
3.2.3 Sediment-Related Transport Processes	3-9
3.2.4 Role of Ice Transport	3-10

3.3 Transport Simulations: The RAIG and Nielsen et al. (1995) Compartmental Models	3-12
3.3.1 RAIG Compartmental Model	3-12
3.3.2 Compartmental Model of Nielsen et al. (1995)	3-20
3.3.3 Model Intercomparisons and Sensitivities	3-21
3.3.4 Simulations of Radionuclide-Release Scenarios	3-28
3.3.5 Predicted Radionuclide Concentrations v. Historic Levels	3-33
3.4 Summary	3-35

4. Bioconcentration of Radionuclides in Marine Food-Web Organisms.. 4-1

4.1 Definition of Bioconcentration Factors	4-1
4.2 Bioconcentration Factors for Radionuclides Derived from FSU Sources ...	4-3
4.3 Bioconcentration Factors for Naturally Occurring Radionuclides	4-5
4.4 Variabilities in Bioconcentration Factors	4-6
4.5 Estimated and Measured Concentrations of Radionuclides in Marine Species	4-12
4.6 Summary	4-12

5. Assessment of Risks to Marine Aquatic Populations Resulting from Exposures to Radionuclides in Arctic Seas 5-1

5.1 Arctic Marine Ecological Systems	5-2
5.2 Tier-I Assessment of Doses to Biota	5-4
5.2.1 Exposure Pathways of Aquatic Populations	5-4
5.2.2 Dosimetry Models	5-4
5.2.3 Standards for Protection of Aquatic Life	5-6
5.2.4 Doses and Dose Rates Potentially Producing Significant Detrimental Effects	5-7
5.2.5 Dose Rates from Potential FSU Radionuclide Contamination of the Arctic Seas	5-13
5.2.6 Dose Rates from Radionuclides Occurring Naturally	5-17
5.2.7 Dose Rates from Fallout Radionuclides in the 1960s and 1990s	5-18
5.3 Uncertainties	5-18
5.3.1 Temperature Effects	5-18
5.3.2 Interaction of Radionuclides with Other Contaminants	5-18
5.4 Tier-II and Tier-III Risk Assessments	5-18
5.5 Summary	5-19

6. Assessment of Risks to Alaskan Populations from Exposures to Radionuclides in Subsistence Diets 6-1

6.1 Subsistence Life-Style	6-2
6.2 Dietary and Harvest Patterns	6-5
6.3 Reference Diets for Specific Communities	6-6
6.3.1 Emmonak	6-6
6.3.2 Diomede	6-6
6.3.3 Kotzebue	6-7
6.3.4 Kivalina	6-7
6.3.5 Point Hope	6-7
6.3.6 Point Lay	6-8
6.3.7 Barrow	6-8
6.3.8 Eastern North Slope Villages	6-8
6.4 Current and Historical Doses from Natural and Background Sources	6-9

6.4.1 Radioactive Materials in Rocks and Soil	6-9
6.4.2 Radioactive Materials in the Body	6-9
6.4.3 Cosmic Rays	6-9
6.4.4 Internal Doses from Natural Radioactivity in Seafoods	6-10
6.4.5 Internal Doses from Historical Man-Made Sources	6-11
6.5 Projected Doses from Russian Nuclear Sources	6-11
6.5.1 Doses Derived from Nuclear Materials Disposed of in the Kara Sea	6-12
6.5.2 Doses from Releases to the Ob and Yenisey Rivers	6-14
6.6 Uncertainty and Sensitivity Analysis	6-14
6.7 Assessment of Risks	6-15
6.8 Risk v. Benefits	6-17
6.9 Summary	6-17

7. Assessment Results, Conclusions, and Recommendations 7-1

7.1 Assessment Context	7-1
7.2 Assessment Results	7-2
7.2.1 Sources	7-2
7.2.2 Transport	7-3
7.2.3 Ecological Risks	7-3
7.2.4 Human Risk	7-4
7.3 Extension of Results to Other Contexts	7-4
7.3.1 Non-Subsistence Residents	7-4
7.3.2 Visitors and Tourism	7-5
7.3.3 Alaska Fishing Industry	7-5
7.4 Possible Use of Results in Future Contexts	7-5
7.5 Conclusions	7-6
7.6 Recommendations	7-6
7.6.1 Monitoring	7-6
7.6.2 Research	7-7
7.6.3 Modeling	7-7
7.6.4 Other	7-7

Appendix A: Ecosystems in Arctic Areas of Concern A-1

A.1 Areas of Concern	A-1
A.1.1 Kara Sea	A-1
A.1.2 Alaskan Shelf: Chukchi and Beaufort Seas	A-1
A.1.3 Northern Bering Sea	A-2
A.2 Types of Ecosystems	A-2
A.2.1 Polar-Ice Ecosystems	A-2
A.2.2 Benthic-Pelagic Ecosystems	A-3
A.2.3 Offshore Pelagic Ecosystems	A-3
A.2.4 Coastal Lagoons	A-3
A.3 Basic Structure and Composition of Ecosystems	A-4
A.4 Marine Populations at Risk	A-4
A.4.1 Ecologically Important Marine Populations at Risk	A-15
A.4.2 Economically Important Marine Populations at Risk	A-15

Appendix B: Radiation Doses and Dose Rates Resulting in Mortality B-1

B.1 Radiation Doses Resulting in Mortality	B-1
B.2 Radiation Dose Rates Resulting in Mortality	B-1

Appendix C: Inherent Radiosensitivity Factors	C-1
C.1 Cell Repopulation and Specialization or Differentiation	C-1
C.2 Biological Repair	C-1
C.3 Adaptive Responses.....	C-2
Appendix D: Subsistence Diets	D-1
Appendix E: Worksheet for Estimating Individual Doses	E-1
Glossary	G-1
References	R-1